MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2016/2017

ETM4106 – OPTOELECTRONICS AND OPTICAL COMMUNICATIONS

(TE)

03 MARCH 2017
09:00 a.m – 11:00 a.m
(2 Hours)

INSTRUCTION TO STUDENTS

1. This question paper consists of 6 pages with **4** Questions only.

2. Attempt **ALL FOUR** questions. All questions carry equal marks and the distribution of the marks for each question is given.

3. Please write all your answers in the Answer Booklet provided.

Question 1

Consider a light with wavelength $\lambda = 1530$ nm, traveling in air strikes a 23 μm core radius of a step index fiber at an angle $\theta_1 = 60^0$, where θ_1 is measured between the incoming ray and the core surface. Upon striking the core, part of the beam is reflected and part is refracted. If the reflected beam makes an angle with the core surface equal to the acceptance angle, and refracted and reflected beams make an angle of 96^0 with each other;

1. What is the refractive index of the core? [3 marks]
2. Consider the refracted beam strikes the cladding of the optical fiber, and the beam totally reflected. What is the refractive index of the cladding? [3 marks]
3. Sketch the path of light [4 marks]
4. What is the numerical aperture? [3 marks]
5. What is the value of V parameter and how many modes propagate in the fiber? [3 marks]
6. Will this fiber be single mode? [3 marks]
7. What percent of optical power flows in the cladding? [3 marks]
8. What is the maximum acceptance angle, when the refracted ray makes and angle with the normal equal 30^0? [3 mark]

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Question 2

(a) Assume an optical network has 20 km of multimode step index fiber with a core refractive index of 1.3, a refractive index difference is 5% and using return to zero code. Determine the following:

1. The delay difference between the slowest and fastest modes at the fiber output. [2.5 marks]
2. The root mean square (rms) pulse broadening due to intermodal dispersion on the link. [2.5 marks]
3. The maximum bit rate that may be obtained without substantial errors on the link assuming only intermodal dispersion. [3 marks]
4. The bandwidth-length product. [3 marks]

(b) As an optical field engineer, your supervisor assigned you to connect an optical fiber network. The network consist of an optical source with a pigtail fiber comprising 50/125 μm graded index fiber with a core index 1.23, refractive index deference 0.03, and a profile parameter of 2.16. The optical source fiber pigtail is spliced to a main transmission fiber comprising 60/125 μm graded index fiber with a core index 1.12, refractive index deference 0.01 and a profile parameter of 2.01. It was stated clearly by your supervisor to have a zero gap, radial or angular misalignment loss. Hence, calculate the insertion loss at the splice point. [14 marks]

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Question 3

The longitudinal modes of a gallium arsenide (GaAs) injection laser emitting at a wavelength of 0.81μm are separated in frequency by 220GHz. If we consider the following:

(a) The gap between the laser source and the fiber is filled with air.
(b) The refractive index of gallium arsenide is 3.4
(c) GaAs injection laser has an optical cavity of width 120 μm
(d) Same mirror reflectivity at each end of the optical cavity.
(e) The current threshold is 70mA
(f) The loss coefficient per cm is 18
(g) The internal quantum efficiency of the laser is 95%.
(h) Assume that the current is confined to the optical cavity.
(i) Number of photons per second that generated by this laser source is 500.
(j) Consider 60% of number of photons per second generated by the laser in section (i) are incident on a PIN photodiode.

Then, determine:

1. The length of the optical cavity. [3 marks]
2. The number of longitudinal modes supported within the structure. [2 marks]
3. The Fresnel reflection loss. [2 marks]
4. The threshold current density. [3 marks]
5. The gain factor for the device. [4 marks]
6. The differential quantum efficiency of the device. [3 marks]
7. Number of injected electrons per second. [3 marks]
8. The quantum efficiency of the PIN photodiode, in case the number of electrons generated by this PIN photodiode is 250. [3 marks]
9. Calculate the responsivity of the PIN photodiode. [2 marks]

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Question 4

(a) As an optical filed engineer, you have the following components:

(a) GaAlAs laser diode operating at 850nm and capable of coupling 1mW (i.e., 0dBm) into fiber
(b) Ten sections of optical fiber each of which is 500m long, each section has two connectors, one for each ends, and each joint point causes loss equal 2dB.
(c) The cable attenuation is 4dB/km
(d) System margin is 6dB
(e) A PIN photodiode receiver with sensitivity -45dBm
(f) An avalanche photodiode receiver with sensitivity -56dBm

1. Use these components, and indicate which receiver (i.e., point (e) or (f)) should be used to construct at least 5km link. [10 marks]
2. Plot the link power budget for 5km only, (i.e., loss versus distance) and indicate all kind of loss, and calculate the received power, when the transmit power is 0dBm. [5 marks]

(b) A 90Gbps NRZ data transmission system uses a GaAlAs laser source diode having a 1nm spectral width. The rise time of the laser transmitter output is 2ns. The transmission distance of the optical fiber is 7km, and the dispersion parameter of the fiber used is 0.07ps/km.nm.

1. If the receiver bandwidth is 90GHz, what is the system rise time? [5 marks]
2. Does this rise time meet the NRZ data requirement of being less than 70% of a pulse width? [5 marks]

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Appendix I

Physical constants:

vacuum permittivity

$$\varepsilon_0 = \frac{10^{-9}}{36\pi} = 8.85418\times10^{-12}\ F/m$$

Vacuum permeability

$$\mu_0 = 4\pi\times10^{-7} = 1.25663\times10^{-6}\ H/m$$

Boltzmann constant

$$k_B = 1.38066\times10^{-23}\ J/K$$

vacuum intrinsic (wave) impedance

$$\eta_0 = 120\pi[\Omega]$$

elementary charge

$$q = 1.60218\times10^{-19}\ C$$

$$1eV = 1.60218\times10^{-19}\ J$$

Plank's constant

$$h = 6.62617\times10^{-34}\ J-s$$

Speed of Light

$$c = 2.998\times10^{8}\ m/s$$